CLAIMS

What is claimed is:

1. A system for interrogating a passive acoustic transponder, producing a transponder signal having characteristic set of signal perturbations in response to an interrogation signal, comprising:

(a) a signal generator, producing an interrogation signal having a plurality of differing frequencies;

(b) a receiver, for receiving the transponder signal;

(c) a mixer, for mixing said transponder signal with a signal corresponding to said interrogation signal, to produce a mixed output;

(d) an integrator, integrating said mixed output to define an integrated phase-amplitude response of the received transponder signal for each of said differing frequencies; and

(e) an analyzer, receiving a plurality of integrated phase-amplitude responses corresponding to said plurality of differing frequencies, for determining the characteristic set of signal perturbations of the passive acoustic transponder.

2. The system according to claim 1, wherein the characteristic set of signal perturbations comprises an acoustic reflection pattern.

3. The system according to claim 1, wherein the characteristic set of signal perturbations comprises a set of phase shifts.

4. The system according to claim 1, wherein said interrogation signal comprises a frequency band having a bandwidth of less than about 5% and having a center frequency in the range of between about 300 MHz to about 30 GHz.

5. The system according to claim 1, wherein said interrogation signal comprises a frequency in a band between about 800 MHz and 1.3 GHz and having a bandwidth of between about 1-3%.

6. The system according to claim 1, wherein said interrogation signal comprises a frequency hopping spread spectrum signal.

7. The system according to claim 1, wherein the characteristic set of signal perturbations comprises a pattern selected from a signal perturbation space having a plurality of degrees of freedom, said interrogation signal having a number of said plurality of differing frequencies no less than the number of degrees of freedom.

8. The system according to claim 1, wherein said plurality of differing frequencies are generated sequentially.

9. The system according to claim 1, wherein at least two of said plurality of differing frequencies are generated simultaneously.

10. The system according to claim 1, wherein said interrogation signal has a pseudorandom sequence of differing frequencies which repeats after a finite duration.

11. The system according to claim 1, wherein the characteristic set of signal perturbations comprises a pattern selected from a signal perturbation space having a plurality of degrees of freedom, said interrogation signal having a number of said plurality of differing frequencies between about 2 to 8 times the number of degrees of freedom.

12. The system according to claim 1, wherein the characteristic set of signal perturbations comprises a pattern selected from a signal perturbation space having a plurality of degrees of freedom, said interrogation signal having a number of said plurality of differing frequencies at least 2 times the number of degrees of freedom.

13. The system according to claim 1, wherein said plurality of differing frequencies are about evenly spaced across a band.

14. The system according to claim 1, wherein said signal generator comprises a digitally controlled oscillator.

15. The system according to claim 1, wherein said signal corresponding to said interrogation signal is delayed with respect to said interrogation signal.

16. The system according to claim 1, wherein said mixer homodynes said transponder signal with a signal corresponding to said interrogation signal to produce, in a steady state condition, a signal whose amplitude corresponds to a relative phase-amplitude difference between said transponder signal and said signal corresponding to said interrogation signal.

17. The system according to claim 1, wherein said mixer comprises a double balanced mixer.

18. The system according to claim 1, wherein said integrator comprises a low pass filter.

19. The system according to claim 1, wherein said integrator integrates said mixed output over a predetermined period.

20. The system according to claim 1, wherein said integrated phase-amplitude response is represented as a scalar value.

21. The system according to claim 1, wherein said integrator interrogation signal has a plurality of successive states, each state having a predetermined period, said integrator comprising a low pass filter having a main time constant of less than about 25% of said period.

22. The system according to claim 1, wherein said characteristic set of signal perturbations of said transponder has a maximum significant time constant of less than about 5 μS and comprises a pattern selected from a signal perturbation space having about 16 degrees of freedom, said transponder integrator interrogation signal being a pseudorandom sequence

frequency hopping signal having about 128 successive different frequencies before repetition, each state having a predetermined period of about 125 μS.

23. The system according to claim 1, wherein said interrogation signal comprises a frequency hopping spread spectrum signal having a dwell period, the characteristic set of signal perturbations of said transponder having a maximum significant time constant of less than about 10% of said dwell period, said integrator being a low pass filter having a cutoff frequency of less than the reciprocal of the maximum significant time constant of the transponder.

24. The system according to claim 1, wherein said integrator comprises a low pass filter having at least two poles in its transfer function.

25. The system according to claim 1, wherein said analyzer evaluates a set of simultaneous equations relating said integrated phase-amplitude responses to the characteristic set of signal perturbations of the passive acoustic transponder.

26. The system according to claim 1, wherein the characteristic set of signal perturbations comprises a pattern selected from a signal perturbation space having a plurality of degrees of freedom, said interrogation signal having a number of said plurality of differing frequencies no less than the number of degrees of freedom, said analyzer solving simultaneous equations for evaluating the degrees of freedom, said analyzer compensating said evaluated degrees of freedom for predetermined variances, evaluating each integrated phase-amplitude response for consistency with a set of remaining integrated phase-amplitude responses, and outputting a compensated, self-consistent data set corresponding to said evaluated degrees of freedom.

27. The system according to claim 26, wherein said interrogation signal is produced intermittently.

28. The system according to claim 1, wherein said signal generator produces said interrogation signal having a plurality of differing frequencies as a substantially complete,

pseudorandomly ordered set of frequencies, which are evenly spaced through an interrogation frequency band.

29. A method for interrogating a passive acoustic transponder, producing a transponder signal having characteristic set of signal perturbations in response to an interrogation signal, comprising:

(a) producing an interrogation signal having a plurality of differing frequencies;

(b) receiving the transponder signal from the passive acoustic transponder;

(c) mixing the transponder signal with a signal corresponding to the interrogation signal, to produce a mixed output;

(d) integrating the mixed output to define an integrated phase-amplitude response of the received transponder signal; and

(e) analyzing a plurality of integrated phase-amplitude responses corresponding to the plurality of differing frequencies, to determine the characteristic set of signal perturbations of the passive acoustic transponder.

30. A method for identifying a passive acoustic transponder, having a set of characteristic signal perturbations selected from a signal perturbation space having a plurality of degrees of freedom, and producing a perturbed signal in response to an interrogation, comprising the steps of:

(a) interrogating the passive acoustic transponder with a frequency hopping spread spectrum signal, having a psueodorandom sequence of a plurality of different frequencies, and a stationary frequency dwell period;

(b) receiving and demodulating the perturbed signal based on a representation of the frequency hopping spread spectrum signal;

(c) determining an average phase-amplitude response of the demodulated perturbed signal during a plurality of dwell periods; and

(d) analyzing the average phase-amplitude response from the plurality of dwell periods to determine the values of the plurality of degrees of freedom.

31. The method according to claim 30, further comprising the steps of:

(e) providing a plurality of passive acoustic transponders;

(f) storing in a database an association of an identification of each passive acoustic transponder with values identifying the values of the plurality of degrees of freedom; and

(g) based on the determined values of the plurality of degrees of freedom, retrieving an identification of a passive acoustic transponder from the database.

32. The method according to claim 30, further comprising the steps of providing a plurality of passive acoustic transponders, each physically associated with an object; storing in a database an association of each passive acoustic transponder with the object, including the values identifying the values of the plurality of degrees of freedom; and based on the determined values of the plurality of degrees of freedom, retrieving an identification of an object associated with the transponder from the database.

33. The method according to claim 30, wherein said frequency hopping spread spectrum signal further comprises a quiet period during which no signal is emitted.

34. A system for determining characteristics of an acoustic wave transponder, producing a transponder signal having characteristic set of signal perturbations in response to an interrogation signal and an internal reference, comprising:

(a) an interrogation signal generator, producing a non-stationary interrogation signal hopping to a plurality of differing frequencies;

(b) a receiver, for receiving the transponder signal;

(c) a demodulator, for demodulating a signal dependent on characteristics of the transponder from said interrogation signal, to produce a demodulated output;

(d) a phase-amplitude detector, detecting a phase-amplitude relationship of said demodulated output with respect to the reference; and

(e) an analyzer, sequentially receiving a plurality of detected phase-amplitude relationships corresponding to said plurality of differing frequencies, for determining the characteristic set of signal perturbations of the acoustic wave transponder.

35. The system according to claim 34, wherein said non-stationary interrogation signal hops to a plurality of differing frequencies as a substantially complete, pseudorandomly ordered set of frequencies, which are evenly spaced through an interrogation frequency band.

36. The system according to claim 34, wherein said interrogation signal generator produces an intermittent signal.

37. A method for analyzing a frequency hopping spread spectrum interrogated passive acoustic transponder comprising the steps of:

receiving a transponder signal;

demodulating the transponder signal with a representation of the interrogation signal;

integrating the demodulated transponder signal from a frequency hop with an effective integration time constant smaller than a duration of the respective frequency hop;

determining a relative phase-amplitude shift of the demodulated signal due to interrogation signal perturbations within the transponder, based on the integrated demodulated transponder signal, over a plurality of frequency hops; and

analyzing the determined phase-amplitude shifts to determine a set of component delays within the transponder.

38. A method for analyzing a frequency hopping spread spectrum interrogated passive acoustic transponder comprising the steps of:

exciting a transponder with a spread spectrum interrogation signal in a plurality of differing excitation states;

receiving modified signals from the transponder under the plurality of differing excitation states;

demodulating the received signals;

filtering the demodulated received signals with a wide bandwidth filter;

determining a characteristic perturbation of the demodulated received signals for each differing excitation state; and

analyzing the determined characteristic perturbations to determine a set of component perturbation elements within the transponder.

39. A method for interrogating a passive acoustic transponder with a non-narrow band frequency interrogation signal having a plurality of differing excitation states, comprising the steps of:

receiving modified signals from the transponder under the plurality of differing excitation states;

demodulating the received signals;

filtering the demodulated received signals with a wide bandwidth filter, having a time constant which is small with respect to the period between transitions of differing excitation states;

determining a characteristic perturbation of the demodulated received signals for each differing excitation state; and

analyzing the determined characteristic perturbations to determine a set of component perturbation elements within the transponder.

40. A passive radio frequency transponder system for reading information encoded into a passive device, having a maximum time constant, as a set of phase-amplitude variations of signals having respective variation time constants shorter than said maximum time constant, comprising the steps of:

exciting the passive device with a set of signals having differing frequency components;

receiving a modified set of signals from the passive device with phase-amplitude variations; and

filtering the received signals with a filter having a time constant comparable in magnitude to the maximum time constant of the passive device.

41. A passive acoustic transponder interrogation system, comprising:

a transponder, producing a transponder signal having characteristic set of signal perturbations in response to an interrogation signal;

a signal generator, producing an interrogation signal having a plurality of differing frequencies;

a receiver, for receiving the transponder signal;

a mixer, for mixing the transponder signal with a signal corresponding to the interrogation signal, to produce a mixed output;

an integrator, integrating the mixed output to define an integrated phase-amplitude response of the received transponder signal; and

an analyzer, receiving a plurality of integrated phase-amplitude responses corresponding to the plurality of differing frequencies, for determining the characteristic set of signal perturbations of the passive acoustic transponder.

42. A method for identifying a passive acoustic transponder or an object associated therewith, comprising:

placing a passive acoustic transponder in proximity to the object, the transponder having a set of characteristic signal perturbations selected from a signal perturbation space having a plurality of degrees of freedom, and producing a perturbed signal in response to an interrogation;

interrogating the passive acoustic transponder with a pseudorandom order, frequency hopping spread spectrum signal, having a sequence of a plurality of different frequencies, and a dwell period;

receiving and demodulating the perturbed signal based on a representation of the pseudorandom order, frequency hopping spread spectrum signal;

determining an average phase-amplitude response of the demodulated perturbed signal during a plurality of dwell periods; and

analyzing the average phase-amplitude response from the plurality of dwell periods to determine the values of the plurality of degrees of freedom.